

PRESSURE SENSOR WITH WATER REPELLENT FILTER

CROSS REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit  
5 of Japanese Patent Applications No. 2000-115530 filed on  
April 17, 2000, No. 2000-115531 filed on April 17, 2000, the  
contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

10 1. Field of the Invention

This invention relates to a pressure sensor so constructed that environmental pressure outside a case is conducted to a sensor element within the case through a filter, and particularly to a pressure sensor used under 15 harsh environment in which the pressure sensor easily takes water.

2. Description of the Related Art

JP-A-9-43085 and JP-A-9-43076 propose this kind of pressure sensors. In the pressure sensor, a sensor element 20 for detecting pressure is disposed within a case into which environmental pressure (atmospheric pressure) and pressure to be measured (measurement pressure) can be introduced so that the sensor element detects a differential pressure between the two pressures. A water repellent filter is 25 further disposed in a passage through which environmental pressure is introduced, and removes dusts, moisture, and the like in the air.

When the conventional pressure sensor as described above is attached to a measurement member such as a fuel tank of a vehicle, the filter is positioned horizontally with a filter surface facing downward. Because of this, if 5 moisture within pressure medium (air) is attached to the filter, the moisture is difficult to be dropped due to surface tension thereof and may clog the filter. The clogged filter closes the introduction passage of environmental pressure, and prevents the sensor from working. Especially 10 in a case where the sensor easily takes water of rainwater or the like, the above problem becomes prominent.

#### SUMMARY OF THE INVENTION

The present invention has been made in view of the 15 above problem. An object of the present invention is to prevent clogging of a filter in a pressure sensor so constructed that environmental pressure is introduced into a case through the filter toward a sensor element unit disposed in the case.

20 According to one aspect of the present invention, briefly, a filter attached to an environmental pressure introduction port, through which environmental pressure is introduced into a case, has a filter surface that is positioned along a gravitational direction when a pressure 25 sensor is used. In the pressure sensor, because the filter surface is positioned along the gravitational direction, moisture attached to the filter surface can easily drop due

to the self-weight thereof. Therefore, the filter can be prevented from clogging with moisture. Preferably, the filter surface has a convex shape protruding outwardly from the case. In this case, moisture attached to the filter 5 surface can drop more easily due to reduced surface tension thereof.

According to another aspect of the present invention, an environmental pressure introduction port covered with a filter is divided into a plurality of opening portions. In 10 this case, even little moisture is liable to condense, so that the removal of moisture can be promoted.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Other features of the present invention will become 15 more readily apparent from a better understanding of the preferred embodiments described below with reference to the following drawings, in which;

FIG. 1 is a cross-sectional view showing a pressure sensor according to a first embodiment of the present 20 invention;

FIG. 2 is a plan view showing the pressure sensor in a direction indicated by arrow II in FIG. 1;

FIG. 3 is an enlarged cross-sectional view showing a sensor element unit in FIG. 1;

25 FIGS. 4A and 4B are enlarged views showing a vicinity of an atmospheric pressure introduction port of the pressure sensor in the first embodiment;

FIG. 5 is a table showing experimental results with respect to an opening area of the atmospheric pressure introduction port;

FIG. 6 is a cross-sectional view showing a pressure sensor according to a second embodiment of the present invention;

FIG. 7A is a plan view showing a main part of the pressure sensor in a direction indicated by arrow VIIA in FIG. 6;

FIG. 7B is an enlarged cross-sectional view showing a part indicated by arrow VIIB in FIG. 6;

FIG. 8 is a schematic view showing a structure of an atmospheric pressure introduction port of the pressure sensor in the second embodiment;

FIG. 9 is an explanatory view showing an effect due to a convex filter surface of a filter in the second embodiment; and

FIG. 10 is an explanatory view showing an effect of gap portions of the filter in the second embodiment.

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#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

##### (First Embodiment)

Referring to FIG. 1, a pressure sensor 100 according to a first embodiment of the invention is so constructed that environmental pressure can be introduced through a filter 12 into a case 1 in which a sensor element unit 4 for detecting pressure is provided. For example, the sensor 100

is attached to a fuel tank (not shown) so that an up-down direction in FIG. 1 corresponds to a vertical direction with respect to the ground (i.e., gravitational direction), and in this case the sensor 100 is used as a fuel pressure 5 sensor for detecting pressure in the tank.

The case 1 is formed by molding resin such as PBT (polybutylene terephthalate) or PPS (polyphenylene sulfide). The case 1 has a recess at the central portion thereof, and the space defined in the recess is divided into a reference 10 pressure chamber 2 into which atmospheric pressure (environmental pressure) is introduced, and a measurement pressure chamber 3 into which measurement pressure such as gasoline vapor is introduced. The sensor element unit 4 is fixed in the recess as a partition between the two chambers 15 2, 3.

At the opposite side of the case 1 with respect to the recess, a pressure introducing portion 1a is provided as a part of the case 1, and protrudes with a cylindrical shape. A pressure introduction passage 1b for introducing 20 measurement pressure toward the sensor element unit 4 is formed in the pressure introducing portion 1a so that the measurement pressure chamber 3 communicates with the outside of the case 1.

An O-shaped ring 17 made of rubber or the like and a 25 holding member (spacer) 18 for holding the O-shaped ring 17 within the introduction passage 1b are attached to an inner wall of the introduction passage 1b. The pressure

introducing portion 1a is connectable to a member such as a  
hose or a pipe extending from the fuel tank so that it can  
communicate with the inside of the fuel tank with the O-  
shaped ring 17 that prevents leakage of pressure transmitted  
5 from the member into the conduction passage 1b.

The sensor element unit 4 is, as shown in FIG. 3,  
composed of a pressure sensitive element 4a made of silicon  
or the like, and a glass base 4b for fixedly holding the  
pressure sensitive element 4a. The pressure sensitive  
10 element 4a is composed of a substrate made of silicon or the  
like and formed with a diaphragm, and is joined to the glass  
base 4b whose thermal expansion coefficient is approximate  
to that of the pressure sensitive element 4a. The glass base  
4b has a through hole, and the pressure sensitive element 4a  
15 detects a differential pressure between atmospheric pressure  
introduced from the reference pressure chamber 2 and  
measurement pressure introduced from the measurement  
pressure chamber 3.

The sensor element unit 4 is fixed to the case 1  
20 through a hollow-shaped stem 5 having a through hole. The  
stem 5 adopts 42-alloy (Fe:Ni=58:42) whose thermal expansion  
coefficient is approximate to that of the glass base 4b. The  
sensor element unit 4 and the stem 5 are fixed together by  
adhesive made of thermosetting resin or the like. The stem 5  
25 and the case 1 are also fixed together by adhesive made of  
thermosetting resin. The measurement pressure conducted from  
the measurement pressure chamber 3 can be transmitted to the

back surface of the pressure sensitive element 4a (surface joined to the glass base 4b) securely by fixing the sensor element unit 4 and the stem 5 to the case 1.

The recess of the case 1 is filled with adhesive 6 such as thermosetting resin and silicone gel 7. The adhesive 6 is to improve air tightness of the fixed portions between the sensor element unit 4 and the stem 5 and between the stem 5 and the case 1. The silicone gel 7 is to improve moisture resistance of the sensor element unit 4. Referring back to FIG. 1, the upper surface of the reference pressure chamber 2 is closed with a lid 8 that is made of resin such as PBT and hermetically fixed by adhesive 9.

Meanwhile, an atmospheric pressure introduction port 10 is provided to externally open at one side of the case 1 to introduce atmospheric pressure (environmental pressure). An atmospheric pressure introduction passage 11 is further formed in the case 1. The atmospheric pressure introduction passage 11 extends from the atmospheric pressure introduction port 10 to the reference pressure chamber 2, and communicates with the reference pressure chamber 2 through a gap provided between the lid 8 and the case 1. Thus, the reference pressure chamber 2 is opened to the air via the atmospheric pressure introduction port 10 and the atmospheric pressure introduction passage 11.

As shown in FIGS. 1 and 2, a water repellent filter (filter portion) 12 composed a sheet made of resin or the like is fixedly attached to the atmospheric pressure

introduction port 10. In the present embodiment, when the sensor 100 is used (that is, when the sensor 100 is attached to the measurement member), the filter surface is positioned approximately in parallel with the gravitational direction 5 as shown in FIG. 1.

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*AT* Here, FIGS. 4A and 4B show enlarged views of the vicinity of the atmospheric pressure introduction port 10. FIG. 4A is an enlarged plan view corresponding to FIG. 2, while FIG. 4B is an enlarged cross-sectional view 10 corresponding to FIG. 1. In FIGS. 2 and 4A, the water repellent filter 12 is hatched. In FIG. 4B, although angle . formed between the filter surface and the gravitational direction is 0., it is not limited to 0.. A preferable range of angle . is 0 to 45..

15 The water repellent filter 12 is formed from a porous sheet made of fluorine system resin such as polytetrafluoroethylene (PTFE) to which a water repellent treatment has been performed. The water repellent filter 12 is assembled with the case 1 by a filter fixation member 20 (spacer) 13 that is formed into a frame shape (rectangular shape in this embodiment) corresponding to the outer wall shape of the atmospheric pressure introduction port 10. The material constituting the filter fixation member 13 is not limited especially, but is the same as that of the case 1 in 25 the present embodiment.

The assembling of the water repellent filter 12 is performed by, for example, disposing the water repellent

filter 12 on the case 1 to cover the atmospheric pressure introduction port 10, press-fitting the fixation member 13 to sandwich the filter 12 with the outer wall of the atmospheric pressure introduction port 10, and adhering the 5 fixation member 13 to the case 1 through adhesive 14 made of epoxy resin to prevent the detachment of the fixation member 13. Accordingly, the water repellent filter 12 and the case 1 are sealed with each other, and dust and moisture are prevented from invading into the reference pressure chamber 10 2 while allowing a flow of air.

On the other hand, the pressure sensitive element 4a that is fixed to the case 1 through the stem 5 has an output terminal for outputting a detection signal, and the output terminal is connected to a terminal 15 through a bonding 15 wire 16. Accordingly, the signal detected by the pressure sensitive element 4a can be taken out to an outside (for example, an ECU of the vehicle or the like).

Next, a method for manufacturing the pressure sensor 100 is explained briefly. First, the case 1 is molded from 20 resin such as PBT or PPS. At that time, the terminal 15 is insert-molded with the case 1 integrally. The water repellent filter 12 is then fixed to the case 1 in the assembling manner as described above. Next, the O-shaped 25 ring 17 and the holding member 18 are attached to the pressure introducing portion 1a of the case 1.

Successively, the pressure sensitive element 4a is adhered to the glass base 4b to form the sensor element unit

4, and the glass base 4b of the sensor element unit 4 is adhered to the stem 5. Further, the stem 5 is adhered to the recess of the case 1. Accordingly, the inside of the recess is divided into the reference pressure chamber 2 and the 5 measurement pressure chamber 3. Next, the output terminal of the pressure sensitive element 4a is wire-bonded to the terminal 15 with the wire 16.

Then, the adhesive 6 is injected into the side of the reference pressure chamber 2 in the recess, and is hardened 10 by a heat treatment or the like. After that, the silicone gel 17 is injected to cover the sensor element unit 4 and the bonding portion, and is hardened as well. Next, the lid 8 is fixed to the upper end wall of the reference pressure chamber 2 by the adhesive 9, thereby hermetically sealing 15 the reference pressure chamber 2. As a result, the pressure sensor 100 is completed.

The pressure sensor 100 thus manufactured is connected to the measurement member with the O-shaped ring 17 that seals the pressure introducing portion 1a, and becomes 20 usable accordingly. The measurement pressure is conducted into the measurement pressure chamber 3 from the measurement member (fuel tank) through the introduction passage 1b, and is transmitted to the back surface of the pressure sensitive element 4a through the hollow portion of the stem 5 and the 25 through hole of the glass base 4b. The measurement pressure transmitted to the pressure sensitive element 4a is, as described above, detected as a differential pressure with

respect to the atmospheric pressure conducted from the reference pressure chamber 2, and is taken out to the outside through the bonding wire 16 and the terminal 15.

According to the present embodiment, the filter 5 surface of the water repellent filter 12 is disposed along the gravitational direction when the sensor 100 is used. Therefore, even when moisture in the environmental pressure medium (air) is attached to the filter surface, the moisture is liable to drop from the filter surface due to the self-weight thereof. Because of this, the water repellent filter 10 12 hardly clogs with moisture, thereby preventing the introduction passage of the environmental pressure from being closed.

For example, when the pressure sensor 100 is attached 15 to the fuel tank, the sensor 100 easily takes water raised by wheels of the vehicle traveling during rain. Even under such harsh environment, according to the pressure sensor 100 of the present embodiment, because the water repellent filter 12 is prevented from clogging by water attached 20 thereto, the sensor characteristics do not deteriorate.

In addition, an opening area of the atmospheric pressure introduction port 10 has been studied in the present embodiment to enhance the above advantage 25 considering that the larger the opening area of the atmospheric pressure introduction port 10 is, the more effectively the advantage for preventing the clogging as described above may be exhibited. Specifically, as a test,

after the entirety of the pressure sensor 100 was immersed into water, the pressure sensor 100 was taken out of water and it was confirmed whether the water repellent filter 12 and the atmospheric pressure introduction port 10 were 5 clogged or not.

Three kinds of pressure sensors 100 according to the present embodiment were formed with various opening areas (48 mm<sup>2</sup>, 90 mm<sup>2</sup>, and 150 mm<sup>2</sup>) of the atmospheric pressure introduction ports 10. Further, as a comparative example, a 10 conventional pressure sensor disclosed in the conventional document described above was formed with an opening area of 28 mm<sup>2</sup>. In each sensor, several (4 to 6) samples were examined in the test described above. The results are shown in FIG. 5. In the sensors of the comparative example and of 15 the present embodiment with the opening area of 48 mm<sup>2</sup>, clogging occurred in at least one sample. To the contrary, in the sensors of the present embodiment with the opening areas of 90 mm<sup>2</sup> and 150 mm<sup>2</sup>, all the samples had no clogging. Accordingly, it is revealed that the effect for preventing 20 clogging can be efficiently exhibited when the opening area of the atmospheric pressure introduction port 10 is 90 mm<sup>2</sup> or more, even under the environment (where the entirety of the sensor is immersed into water) harsher than the ordinal usage environment.

25 (Second Embodiment)

In a second embodiment of the present invention, the structures of the water repellent filter 12 and the

atmospheric pressure introduction port 10 are modified from those in the first embodiment. In the second embodiment, the same parts as those in the first embodiment are designated with the same reference numerals, and the same explanations 5 are not reiterated.

FIG. 6 shows a pressure sensor 100a in the second embodiment, and FIGS. 7A and 7B show a main part of the pressure sensor 100a. Specifically, FIG. 7A is a plan view corresponding to FIG. 4A and FIG. 7B is a cross-sectional

10 view corresponding to FIG. 4B. FIG. 8 shows a detailed structure of the atmospheric pressure introduction port 10 from which the water repellent filter 12 and the filter fixation member 13 are detached.

In the first embodiment described above, the 15 atmospheric pressure introduction port 10 is composed of a single opening portion. As opposed to this, in the present embodiment, as shown in FIG. 7A, the atmospheric pressure introduction port 10 is composed of several (three in the figure) opening portions 21 divided by a frame 20. Each of 20 the opening portions 21 has an elongated shape elongated in the gravitational direction. In this embodiment, each of the opening portions 21 has a rectangular shape with a long side parallel to the gravitational direction.

Here, in the atmospheric pressure introduction passage 25 11, a passage part extending from the atmospheric pressure introduction port 10 to the side of the reference pressure chamber 2 (in the lateral direction in FIG. 7B) is referred

to as a first passage 11a, and a passage part extending from the first passage 11a to the side of the lid 8 (in the vertical direction in FIG. 7B) is referred to as a second passage 11b. In the present embodiment, several first 5 passages 11a are provided in parallel to correspond to the several opening portions 21, and a single second passage 11b is provided to join and communicate with the several first passages 11a.

Also, although the filter surface of the water 10 repellent filter 12 is approximately flat (slightly convex) in the first embodiment, as shown in FIG. 7B, the filter surface has a convex shape protruding outward (more largely) from the case 1 in the second embodiment. Specifically, as shown in FIGS. 7B and 8, the frame 20 for dividing the 15 opening portions 21 is formed with protrusions 22 protruding to the outside of the case 1, and the filter surface of the water repellent filter 12 is disposed in contact with the distal ends of the protrusions 22. Accordingly, the filter surface can form the convex shape in accordance with the 20 protruding heights of the protrusions 22.

As shown in FIG. 8 with hatching (that is not a cross-section), the protrusions 22 are not provided at a part of peripheral edge portions of the opening portions 21, and gap portions 23 are provided between the frame 20 and the filter 25 surface where the protrusions 22 are not provided. Therefore, the atmospheric pressure can be introduced into the opening portions 21 through the filter surface of the water

repellent filter 12 and the gap portions 23.

According to the second embodiment, like the first embodiment, the filter hardly clogs with water and the like, and the environmental pressure introduction passage can also 5 be prevented from clogging. In addition, the following advantages can be provided.

First, because the filter surface of the water repellent filter 12 is formed with a convex (curved) shape such as an R-like shape or a spherical shape protruding 10 outwardly from the case 1, the surface tension of water can be reduced as compared to the case where the filter surface is flat. Because of this, for example, as shown in FIG. 9, even when moisture or foreign matter K1 such as dust is attached to the filter surface of the water repellent filter 15 12, it can be dropped more easily in comparison with the case where the filter surface is flat.

When the protrusions 22 include upper and lower protrusions arranged in the gravitational direction as shown in FIG. 7B, the upper protrusion preferably has a protruding 20 height larger than that of the lower protrusion to enhance the above advantages. Here, in the first embodiment described above, the water repellent filter 12 may be assembled with the case 1 to have a convex filter surface protruding to the outside of the case more largely. In this 25 case, the same advantages as those of the first embodiment can be provided.

Also, according to the second embodiment, because the

atmospheric pressure introduction port 10 is composed of several opening portions 21 divided by the frame 20, a contact area of air flowing in the port 10 and moisture is increased due to the frame 20 in comparison with the case 5 where the atmospheric pressure introduction port 10 is composed of a single opening portion, so that even a little moisture can be promoted to condense. As a result, moisture is collected by the water repellent filter 12 and is prevented from invading inside the filter 12. In consequence, 10 the water removing performance of the filter 12 can be enhanced. That is, moisture condenses and drops from the filter 12 more easily, so that moisture can be removed more efficiently.

Further, according to the second embodiment, because 15 the gap portions 23 capable of introducing atmospheric pressure (environmental pressure) are provided between the frame 20 and the filter surface of the water repellent filter 12, the gap portions 23 can securely conduct the atmospheric pressure toward the sensor element unit 4 even 20 if the filter surface clogs.

For example, as shown in FIG. 10, even if foreign matter K2 such as dirt is attached to the filter surface of the water repellent filter 12 to close one of the opening portions 21, the communication between the outside and the 25 opening portion 21 can be attained because the gap portions 23 are provided as hatched in FIG. 10. Therefore, the atmospheric pressure introduction passage can be securely

prevented from being closed as long as the entire region of the filter surface is clogged with foreign matters.

In the above-described embodiments, the present invention is applied to a relative pressure sensor for 5 detecting a differential pressure between atmospheric pressure and measurement pressure; however, the present invention is not limited to that, but may be applied to various sensors such as a pressure sensor that detects a pressure based on atmospheric pressure (environmental 10 pressure) as absolute pressure introduced toward a sensor element unit. That is, the feature of the present invention is, in a pressure sensor for introducing through a filter environmental pressure from an outside of a case toward a sensor element unit disposed within the case, the filter 15 surface of the filter attached to an induction port of the case is disposed approximately along the gravitational direction, and the other features may be changed appropriately.

While the present invention has been shown and 20 described with reference to the foregoing preferred embodiments, it will be apparent to those skilled in the art that changes in form and detail may be made therein without departing from the scope of the invention as defined in the appended claims.